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Felder et al.

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(54) **CURRENT THRESHOLD CIRCUIT**

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(51) **Int. Cl.**
H03F 3/04 (2006.01)

(52) **U.S. Cl.** **330/298**

(58) **Field of Classification Search** .... None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,277,755 A * 7/1981 Fausone et al. 330/128
4,410,859 A * 10/1983 Kuwahara 330/298
4,860,154 A * 8/1989 Fazlollahi 361/101
5,162,671 A * 11/1992 Ishihara 327/74
5,363,063 A * 11/1994 Laot et al. 330/298
5,384,549 A * 1/1995 Araki 330/298
5,877,655 A * 3/1999 Maige 330/298
6,064,266 A * 5/2000 Anderson et al. 330/284
6,489,813 B1 * 12/2002 Kulhalli et al. 327/77
6,867,652 B1 * 3/2005 Hastings et al. 330/298
6,980,058 B1 * 12/2005 Noro 330/298

* cited by examiner

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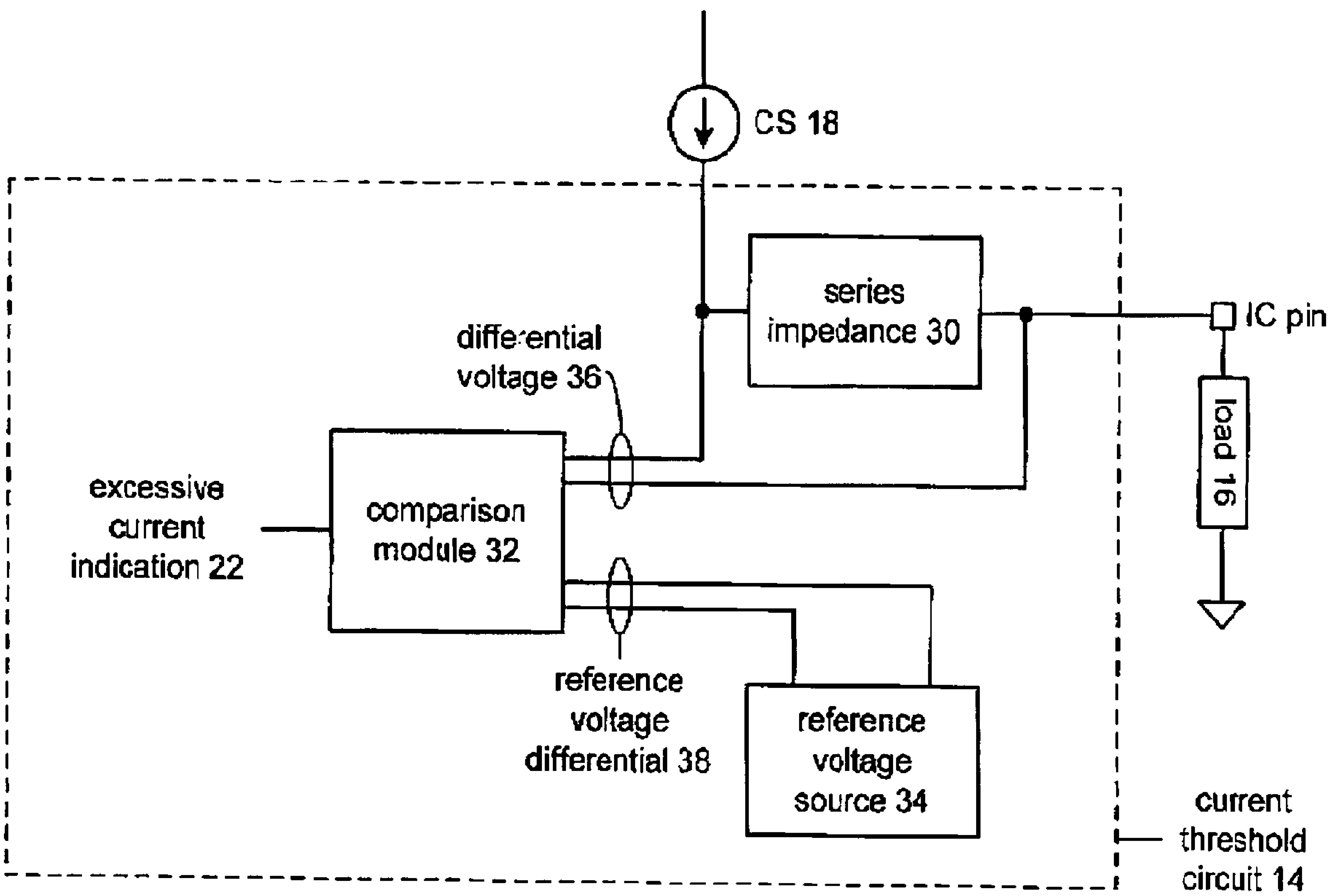
(57) **ABSTRACT**

A current threshold circuit includes a series impedance, a reference voltage source, and a comparison module. The series impedance couples an output of a current source to a load, wherein impedance of the series impedance is substantially less than impedance of the load. The reference voltage source is operably coupled to produce a reference voltage differential. The comparison module is operably coupled to compare the reference voltage differential with a differential voltage of the series impedance, wherein the comparison module generates an excessive current indication when the differential voltage of the series impedance compares unfavorably to the reference voltage differential.

19 Claims, 8 Drawing Sheets



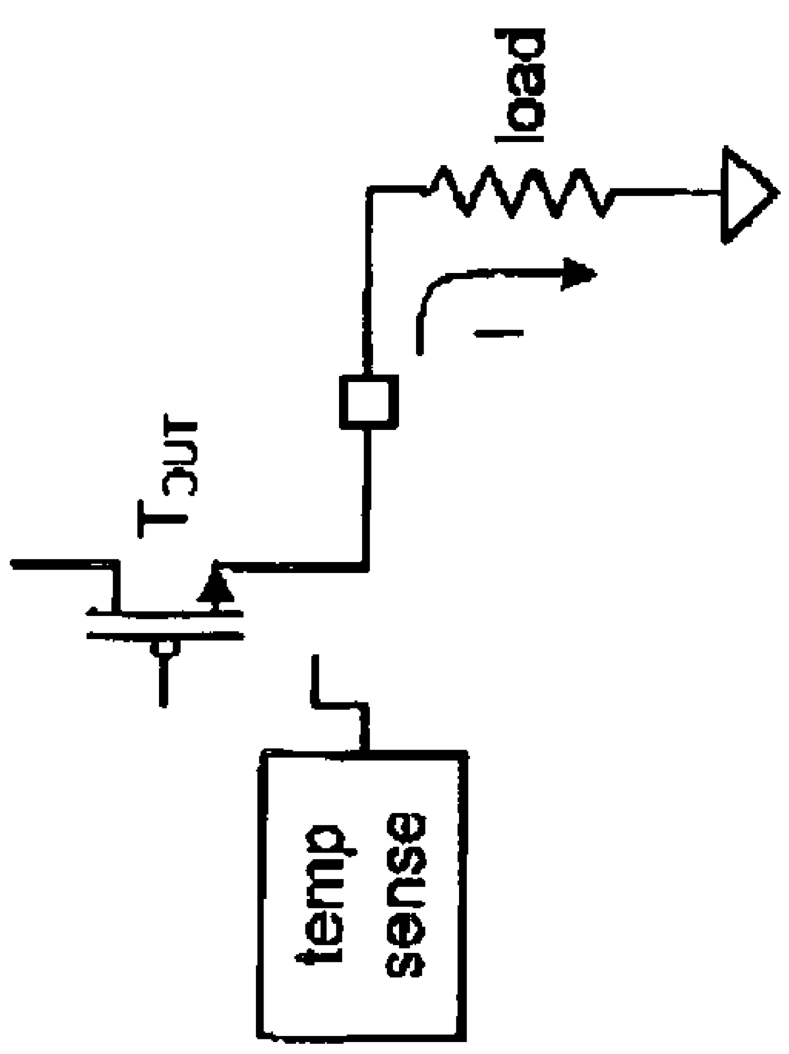


FIG. 1
(prior art)

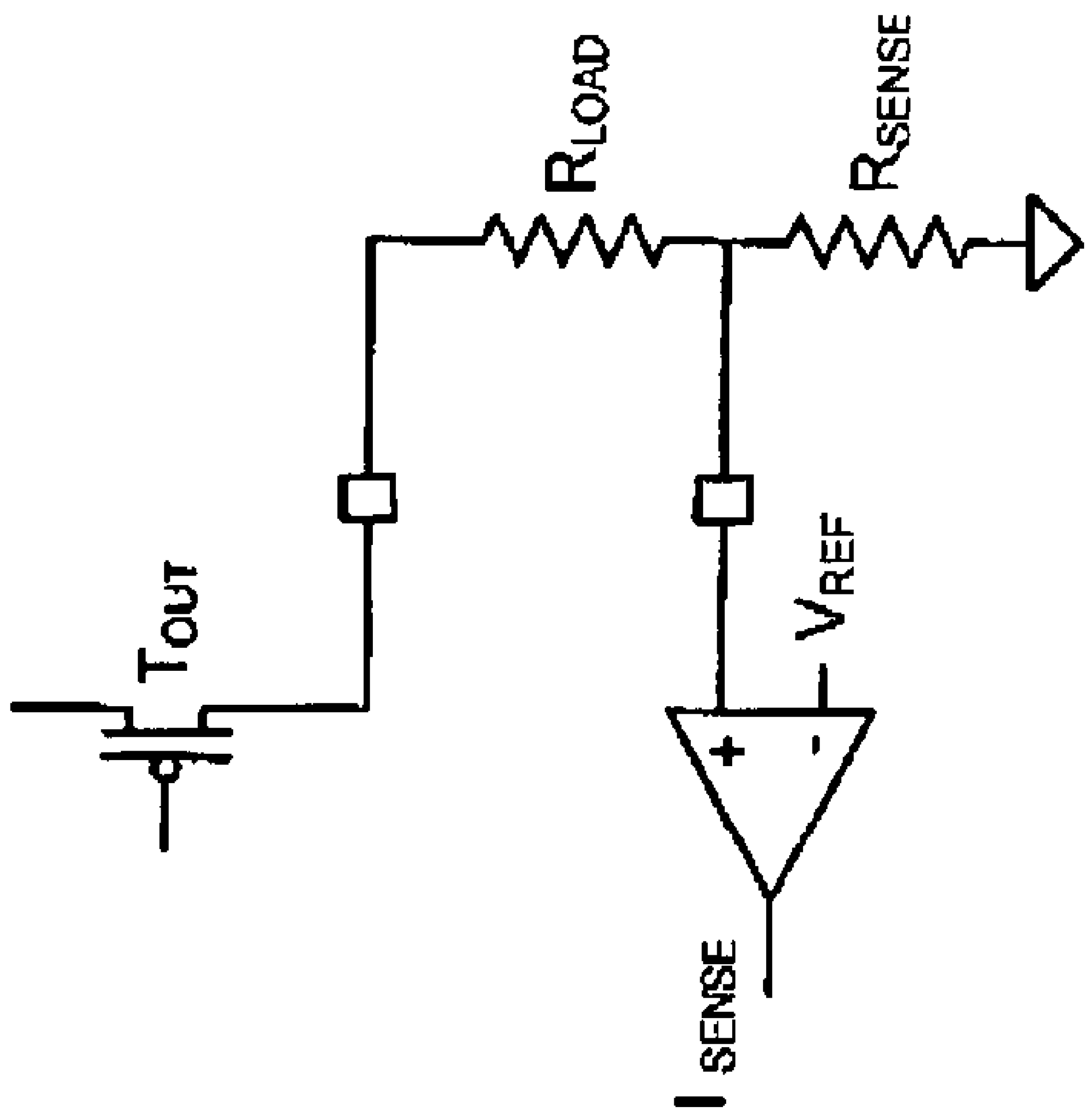


FIG. 2
(prior art)

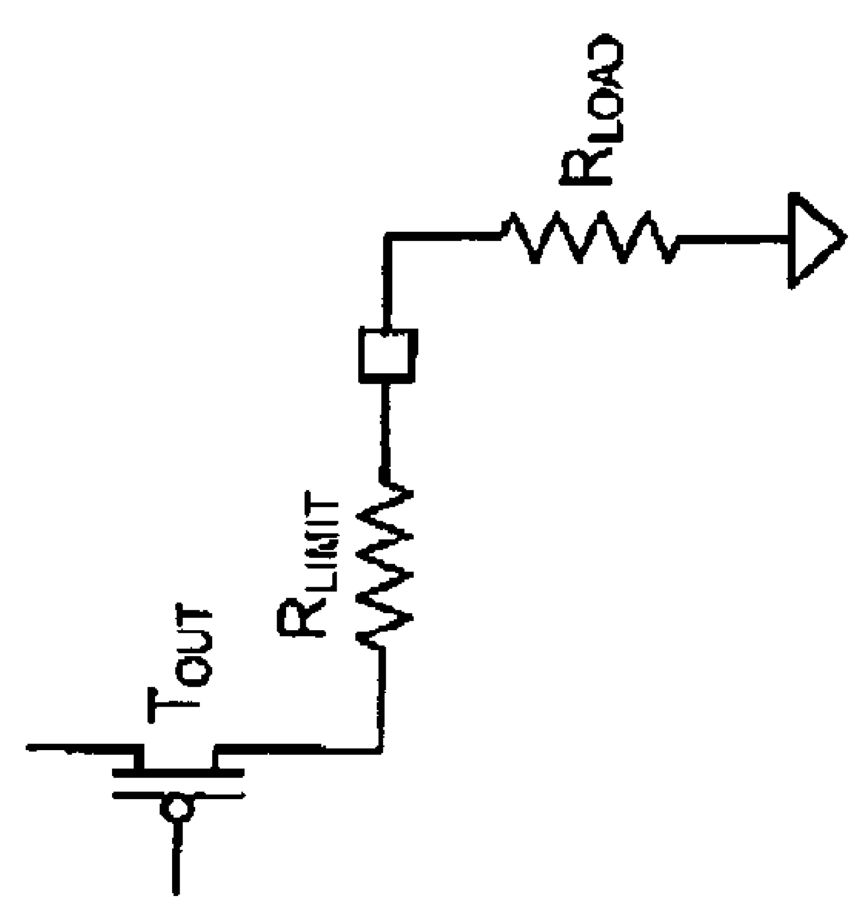


FIG. 3
(prior art)

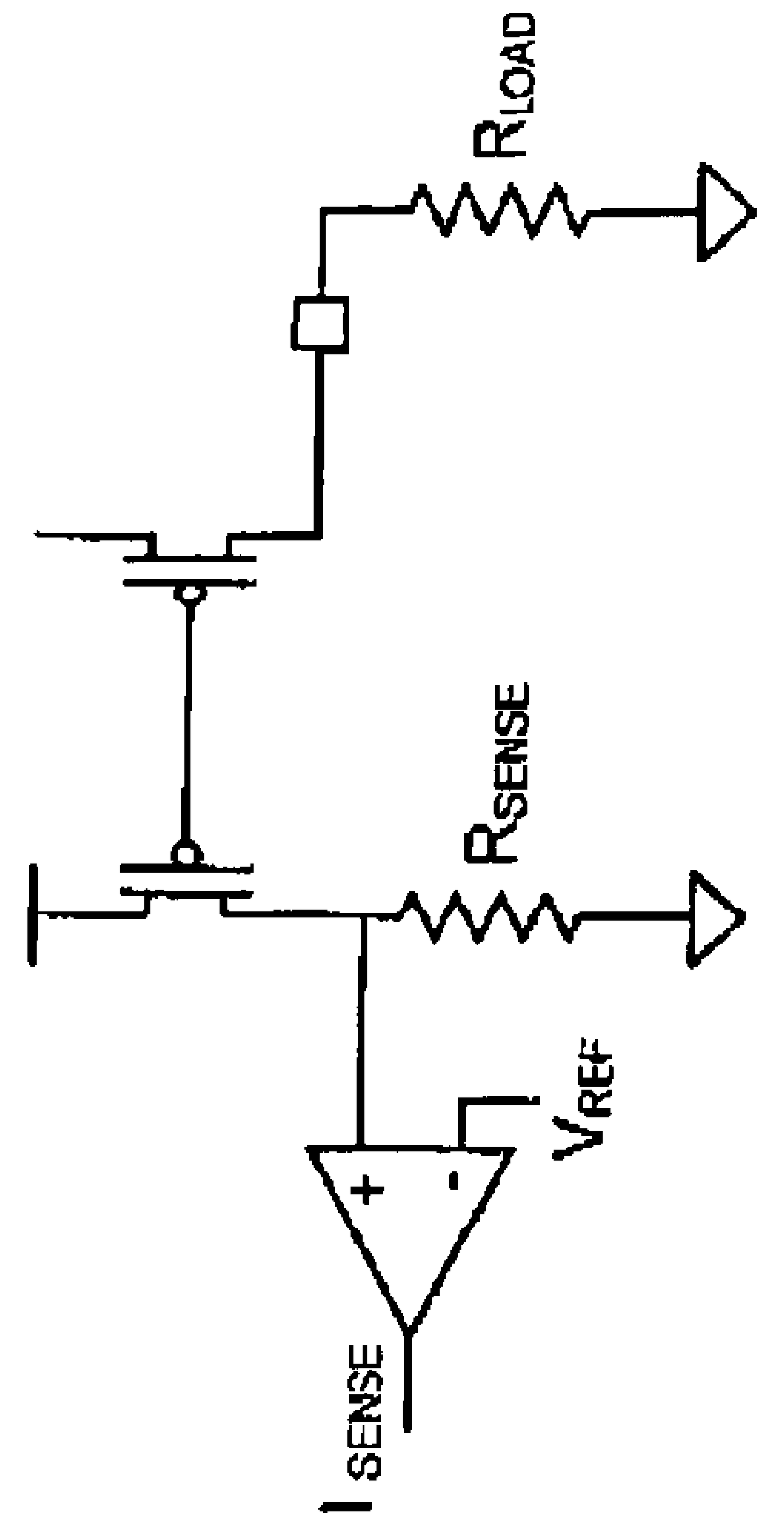


FIG. 4
(prior art)

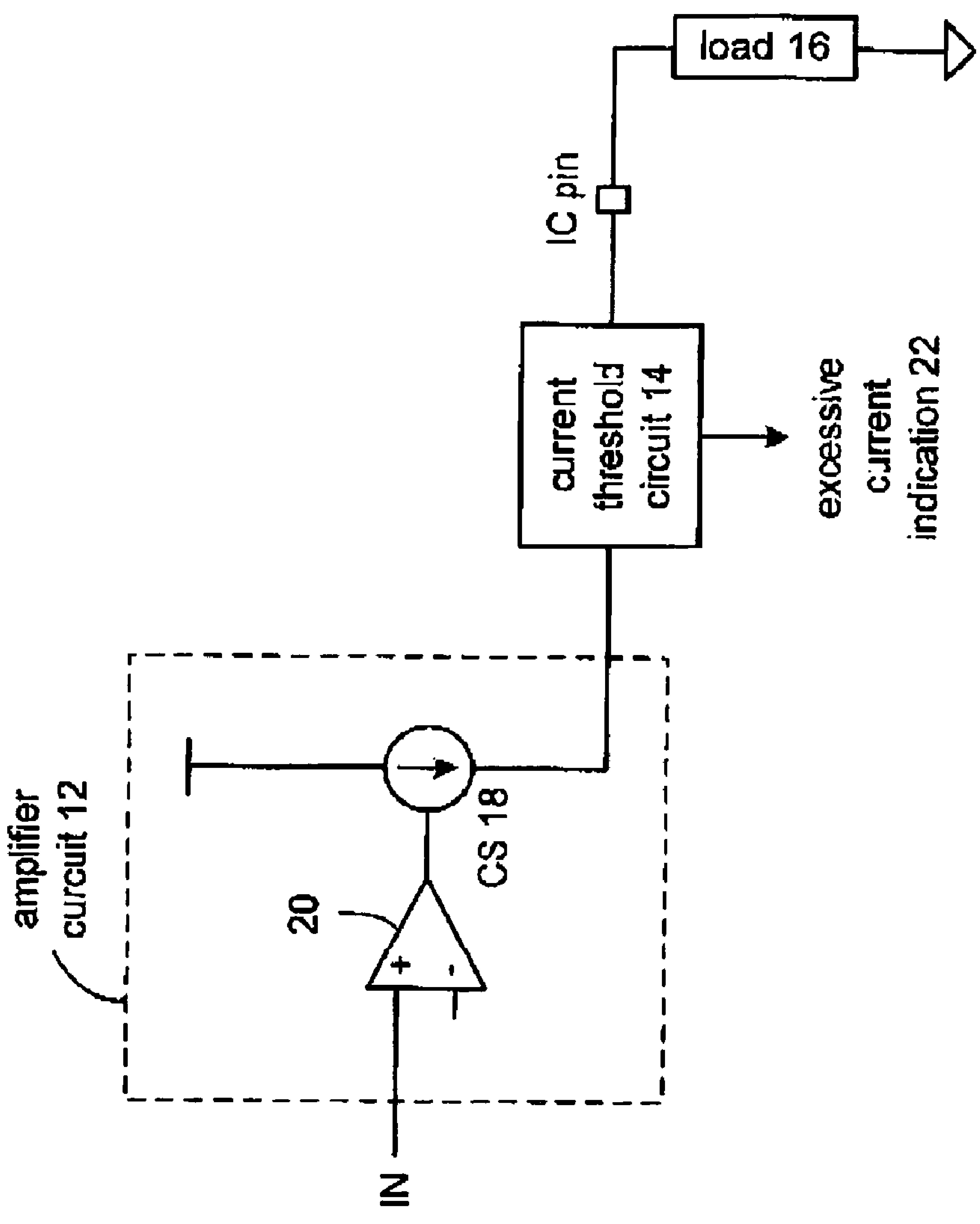


FIG. 5
high current output circuit 10

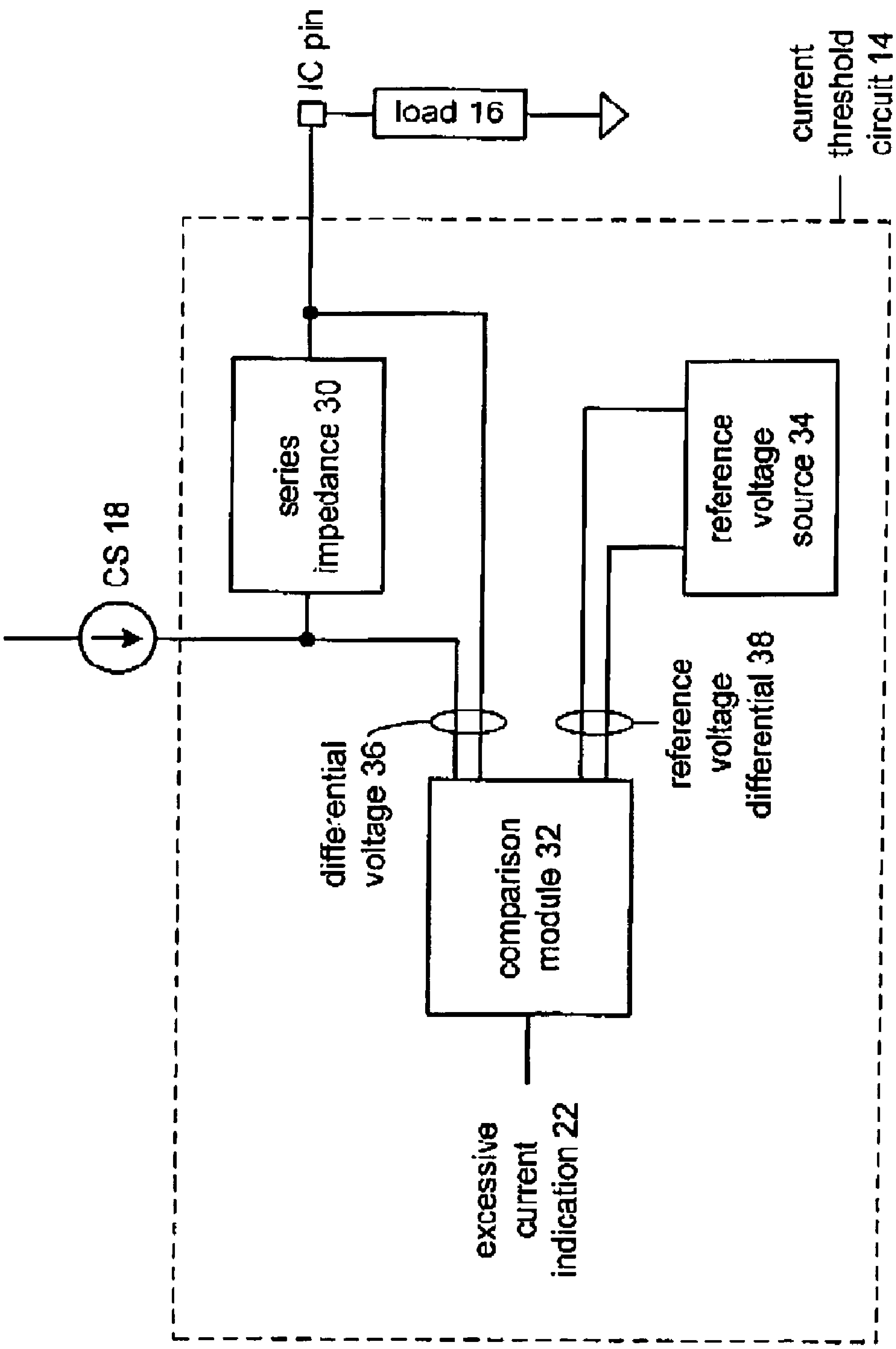

IC pin
load 16
current threshold circuit 14
CS 18
series impedance 30
reference voltage source 34
differential voltage 36
reference voltage differential 38
comparison module 32
excessive current indication 22

FIG. 6

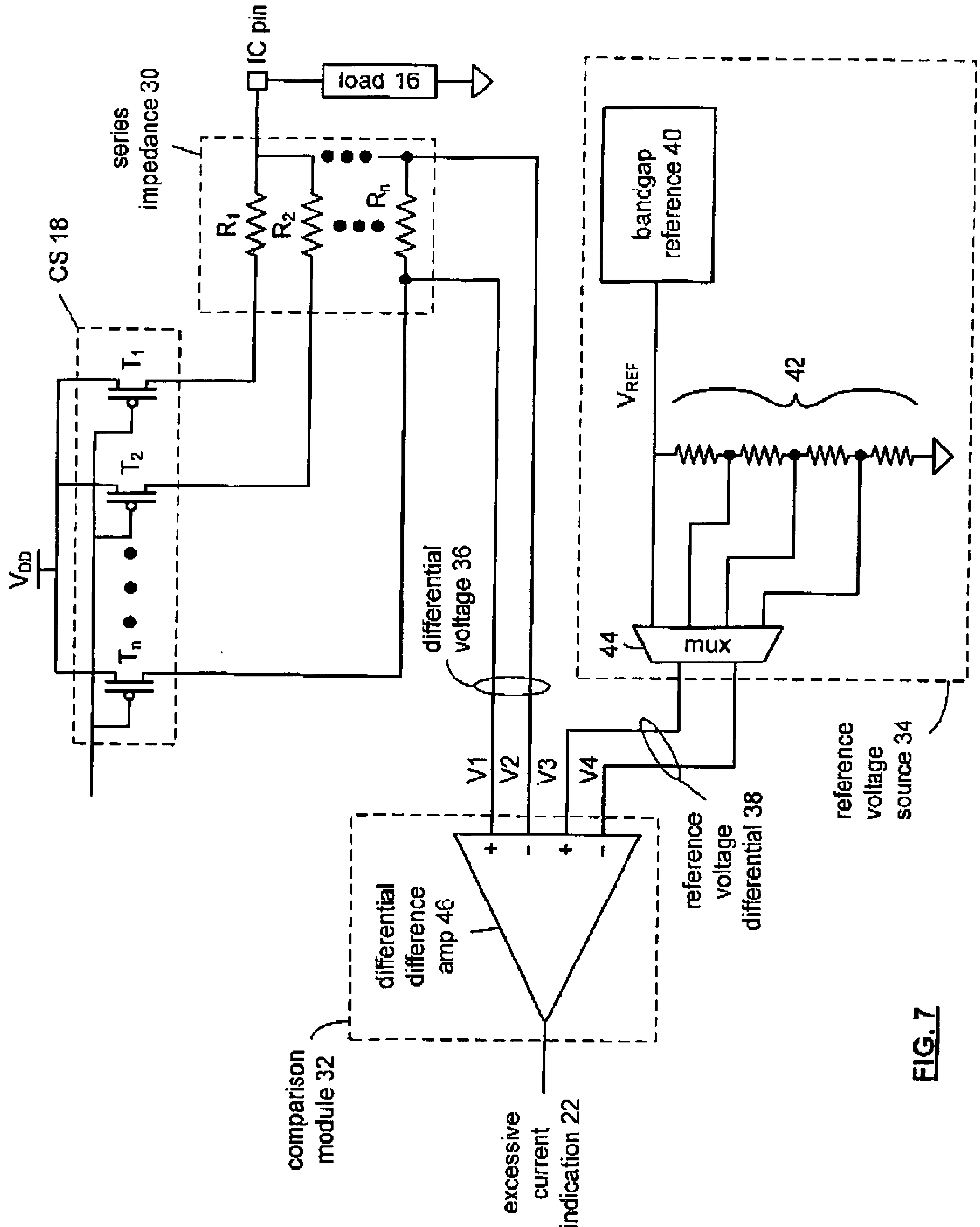

IC pin
load 16
series impedance 30
CS 18
V_{DD}
T_1
T_2
T_n
R_1
R_2
R_n
bandgap reference 40
V_{REF}
42
mux
44
differential voltage 36
V1
V2
V3
V4
reference voltage differential 38
reference voltage source 34
differential difference amp 46
comparison module 32
excessive current indication 22

FIG. 7

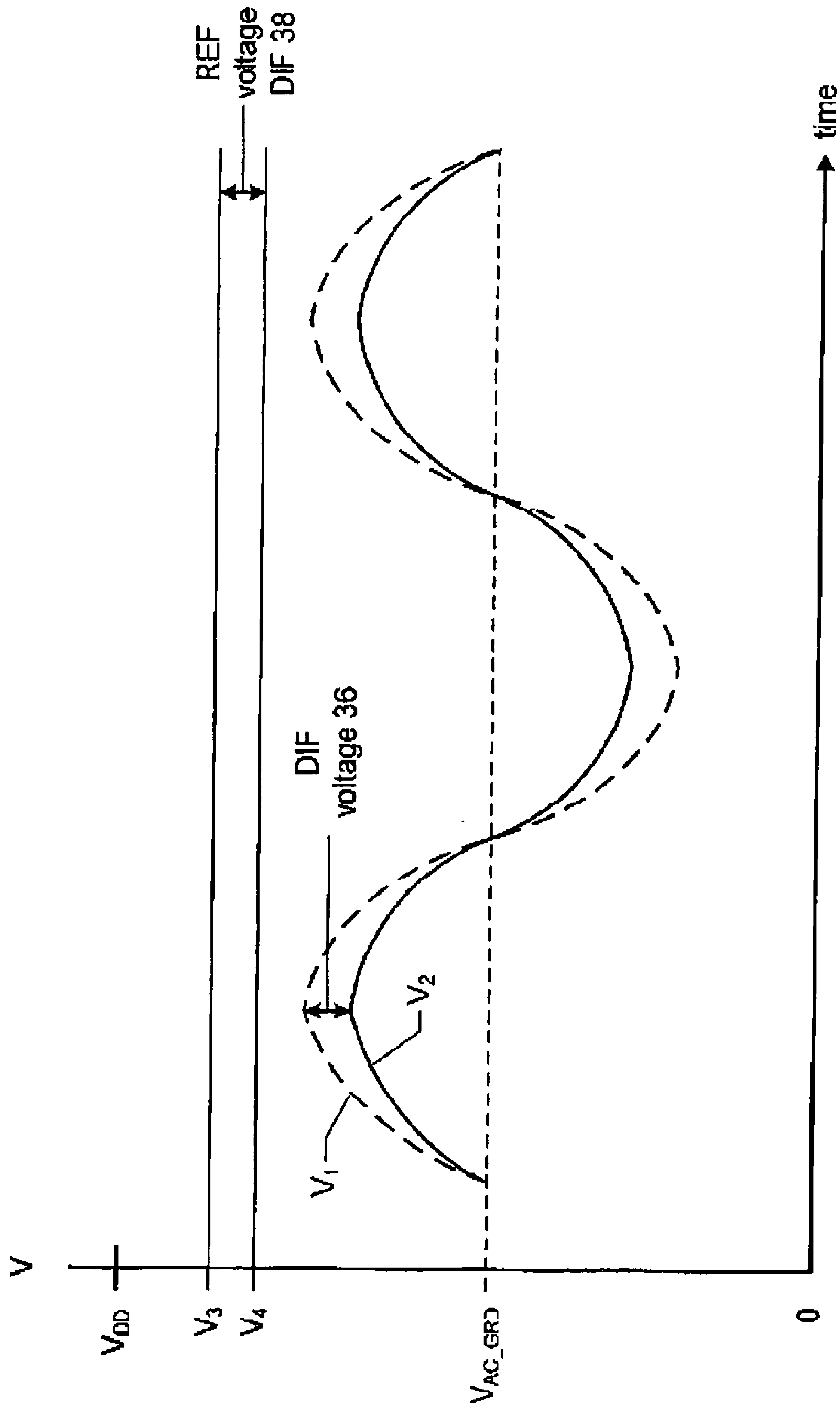
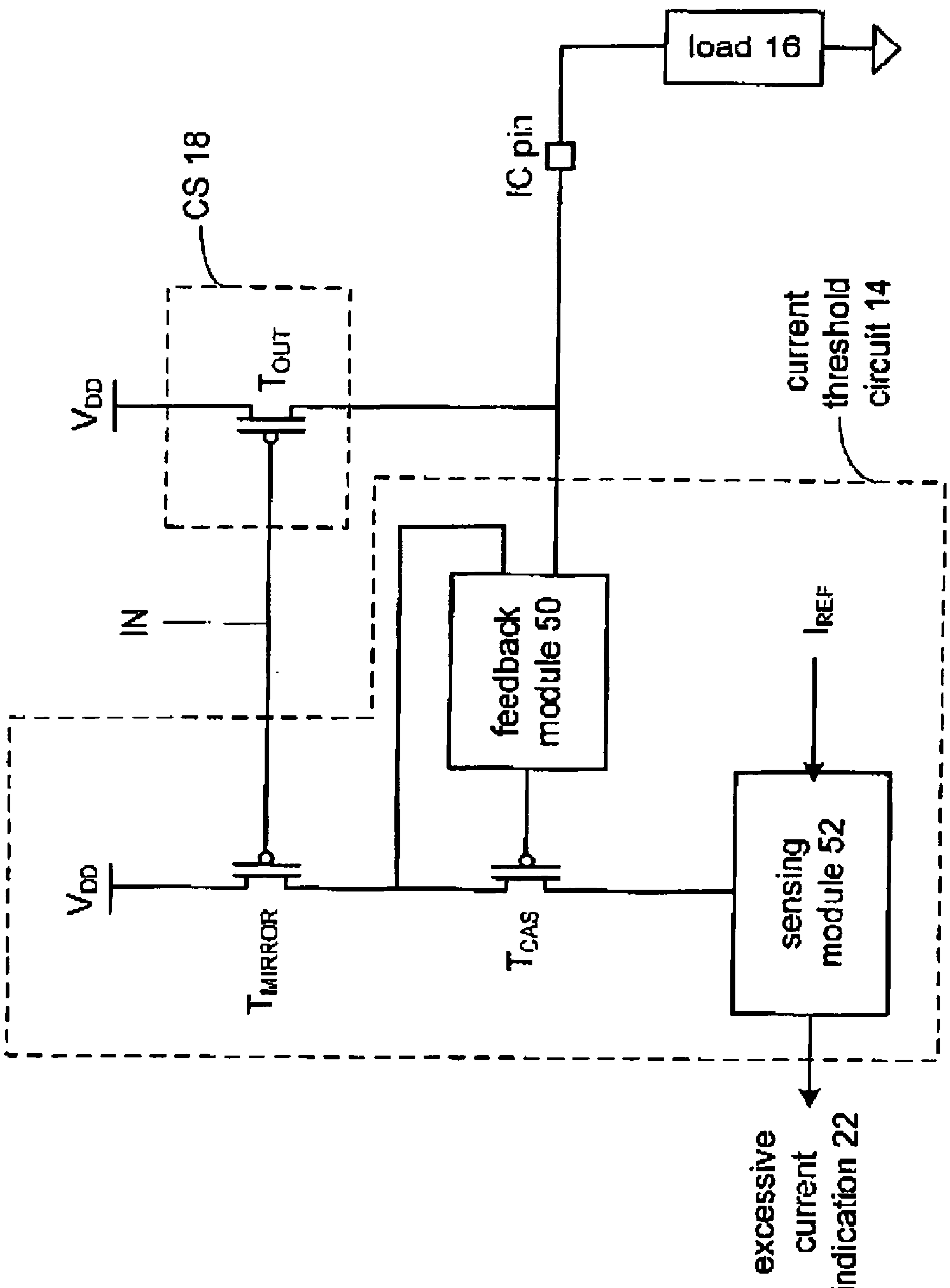


FIG. 8
function of comparison module 32



load 16
IC pin
CS 18
V_{DD}
T_{OUT}
current threshold circuit 14
IN
feedback module 50
I_{REF}
V_{DD}
T_{MIRROR}
T_{CAS}
sensing module 52
excessive current indication 22

FIG. 9

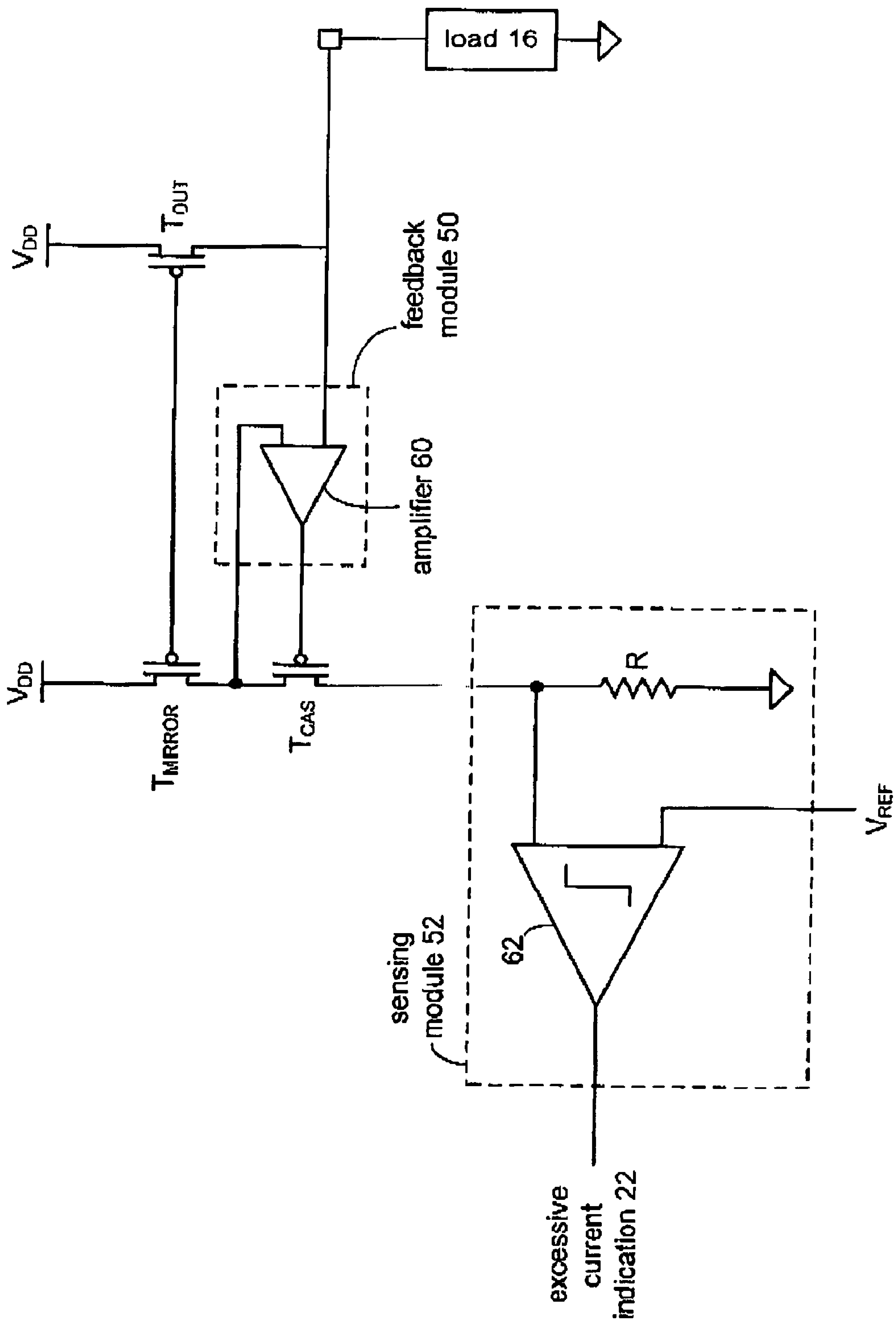

load 16
VDD
TOUT
feedback module 50
amplifier 60
VDD
TMRROR
TCAS
R
VREF
62
sensing module 52
excessive current indication 22

FIG. 10

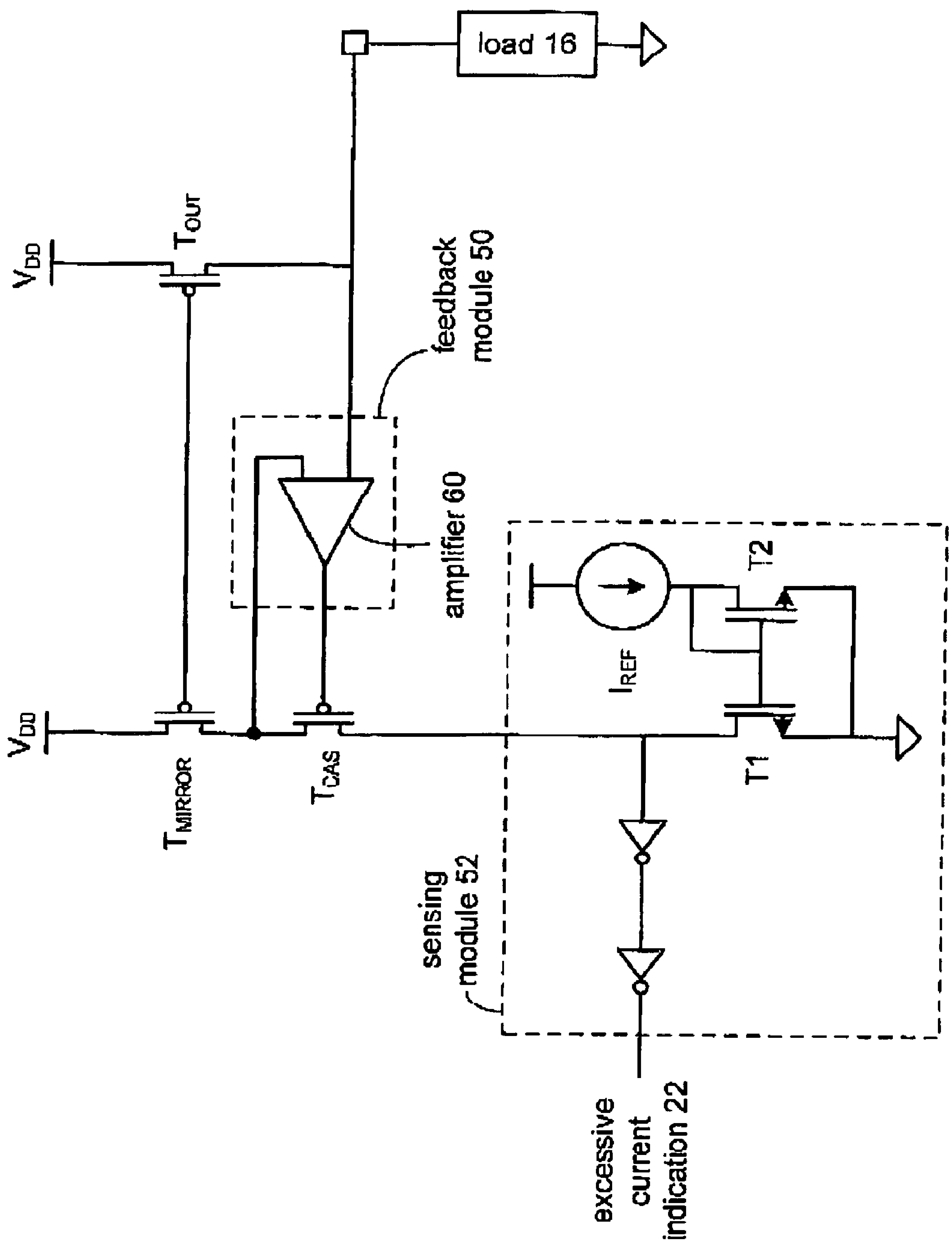

load 16
V_{DD}
T_{OUT}
feedback module 50
amplifier 60
V_{DD}
T_{MIRROR}
T_{CAS}
I_{REF}
T2
T1
sensing module 52
excessive current indication 22

FIG. 11

CURRENT THRESHOLD CIRCUIT

BACKGROUND OF THE INVENTION

1. Technical Field of the Invention

This invention relates generally to integrated circuits and more particularly to excessive output current detection of such integrated circuits.

2. Description of Related Art

Integrated circuits (IC) are known to be used in a multitude of electronic devices and are required to provide sufficient output power to driver components coupled to the IC. For example, an audio processing IC (e.g., audio codec, MP3 player, etc.) has at least one output to drive headphones. To protect an IC from an overload and/or short circuit on such a high powered output, the IC includes a current limiting circuit.

FIG. **1** is an embodiment of a known output current limit circuit that includes an output drive transistor (T_{out}) and a temperature sensing circuit that is in the vicinity of the transistor. The output drive transistor provides an output current to a load via an IC pin. If the output current becomes excessive, the output drive transistor heats up, which is sensed by the temperature sensing circuit. When the temperature of the output drive transistor becomes too high, due an overload or a short, the temperature sense circuit provides an overload current signal to a processor, which disables the output drive transistor. While such a circuit provides overload protection, it does so at the cost of a temperature sensing circuit, which may not respond fast enough to avoid overloading the power rails.

FIG. **2** is a schematic block diagram of another known current sensing circuit. In this embodiment, a sense resistor (R_{sense}) is coupled in series with the load (R_{load}) off chip. The output transistor, which is on chip, drives the series combination of the resistive load and the sense resistor. An amplifier, or comparator, monitors the voltage across the sense resistor with respect to a reference voltage. When the voltage across the sense resistor exceeds a voltage reference, a current limit signal (I_{sense}) is produced. While this provides overload protection, it does at the cost an additional sense pin for each output. Further, the sense resistor adds impedance to the output, which lowers the overall effeciency of the output due to its power consumption and reduces the voltage swing of the output.

FIG. **3** is another embodiment of a known current limiting circuit for an output of an integrated circuit. In this embodiment, a limiting resistor (R_{limit}) is coupled in series with the resistive load (R_{load}). The limiting resistor is on-chip with the output transistor (T_{out}) and has an impedance substantially equal to the resistive load. An issue with this embodiment is the loss of voltage output swing for the resistive load as well as the inefficiency due to power consumption of the limiting resistor.

FIG. **4** is yet another embodiment of a known current limiting circuit. In this embodiment, the output transistor T_{out} drives the load resistance and the output current is mirrored to a sense circuit. The sense circuit includes a current mirroring transistor, a sense resistor and a comparator, or amplifier. In operation, the output current is mirrored by the mirroring transistor, where the mirrored current is provided to the sense resistor (R_{sense}). The sense resistor produces a sensed voltage based on the mirrored current, where the sense current is compared with a reference voltage. When the sensed voltage exceeds the reference voltage, an overload condition (I_{sense}) exists. An issue with this embodiment of a current limiting circuit is that when the output voltage swings from rail-to-rail, the drain source voltage of the output transistor has a wide variation, which causes the mirroring transistor to produce an inaccurate mirroring current. Such inaccurate current mirroring cause unacceptable variations in the current limiting function.

Therefore, a need exists for a current threshold and/or limiting circuit that overcomes the drawbacks of previous current limiting and/or current sensing circuits.

BRIEF SUMMARY OF THE INVENTION

The current threshold circuit of the present invention substantially meets these needs and others. In one embodiment, a current threshold circuit includes a series impedance, a reference voltage source, and a comparison module. The series impedance couples an output of a current source to a load, wherein impedance of the series impedance is substantially less than impedance of the load. The reference voltage source is operably coupled to produce a reference voltage differential. The comparison module is operably coupled to compare the reference voltage differential with a differential voltage of the series impedance, wherein the comparison module generates an excessive current indication when the differential voltage of the series impedance compares unfavorably to the reference voltage differential.

In another embodiment, a current threshold circuit includes a current mirroring transistor, a cascode transistor, a feedback module, and a sensing module. The current mirroring transistor is operably coupled to an output transistor of a current source. The cascode transistor is operably coupled in series with the current mirroring transistor. The feedback module is operably coupled to generate a gate voltage for the cascode transistor such that a drain voltage of the current mirroring transistor substantially equals a drain voltage of the output transistor. The sensing module is operably coupled to compare a representation of a current of the current mirroring transistor with a representation of a reference current level, wherein the sensing module generates an excessive current indication of the output transistor when the representation of the current of the current mirroring transistor compares unfavorably with the representation of the reference current level.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIGS. **1**–**4** are schematic block diagrams of prior art current sensing circuits;

FIG. **5** is a schematic block diagram of a high current output circuit in accordance with the present invention;

FIG. **6** is a schematic block diagram of a current threshold circuit in accordance with the present invention;

FIG. **7** is a schematic block diagram of another embodiment of a current threshold circuit in accordance with the present invention;

FIG. **8** is a graph depicting the function of the comparison module of the current threshold circuit in accordance with the present invention;

FIG. **9** is a schematic block diagram of another embodiment of a current threshold circuit in accordance with the present invention;

FIG. **10** is a schematic block diagram of yet another embodiment of a current threshold circuit in accordance with the present invention; and

FIG. **11** is a schematic block diagram of yet a further embodiment of a current threshold circuit in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **5** is a schematic block diagram of a high current output circuit **10** that includes an amplifier circuit **12**, a current threshold circuit **14**, an integrated circuit (IC) pin and a load **16**. The amplifier circuit **12** and the current threshold circuit **14** are implemented on an integrated circuit while the load is typically off-chip. The amplifier circuit **12** may be an amplifier and/or a line driver. The load may be a speaker, headphone, et cetera.

The amplifier circuit **12** includes an amplifier **20** and a current source **18**. The output of the amplifier **20** regulates the current produced by current source **18**. In one embodiment, the amplifier **20** may be connected as an amplifier where the positive input is coupled to receive an input signal and the negative input is coupled to a reference voltage or other reference source. Alternatively, the amplifier circuit **12** may be used as a line driver where the positive input of the amplifier receives the input signal and the negative input of the amplifier is coupled to the output of the amplifier producing a unity gain amplifier. As one of ordinary skill in the art will appreciate, the amplifier **20** may be configured in a multitude of ways including, but not limited to, inverting single-ended amplifier and a differential amplifier. The current source **18** may include one or more output transistors that provide current to the load via the current sense threshold **14** and the integrated circuit pin.

The current threshold circuit **14** is operably coupled to sense the current provided by the current source **18** to the load **16**. When the current exceeds a pre-determined threshold, the current threshold circuit **14** generates an excessive current indication. Other circuitry on the integrated circuit interprets the excessive current indication **22** to adjust the amplifier circuit **12** by reducing the current it provides and/or by disabling the amplifier circuit **12**. For example, if the IC pin is shorted to ground, the current threshold circuit **14** generates an excessive current indication **22** which may be used to disable the amplifier circuit **12**.

FIG. **6** is a schematic block diagram of an embodiment of the current threshold circuit **14**. In this embodiment, the current threshold circuit includes a series impedance **30**, a comparison module **32**, and a reference voltage source **34**. The series impedance **30** is coupled in series with the current source **18** of the amplifier circuit **12** and with the load **16** via the integrated circuit pin. The comparison module **32** has two pairs of inputs. The 1^{st} pair of inputs receives the voltage imposed across the series impedance **30** as a differential voltage **36**. The other pair of inputs of the comparison module is provided by the reference voltage source **34** as a reference voltage differential **38**.

The comparison module **32** compares the differential voltage **36**, which represents the voltage imposed across the series impedance **30**, with the reference voltage differential **38** to produce the excessive current indication **22**. In this implementation, the comparison module **32** substantially reduces issues related to common mode voltage of sensing an on-chip series impedance and/or issues related to rail-to-rail swings of the output. Further note that the impedance of the series impedance **30** is substantially less than the impedance of the load **16**. For instance, the series impedance **30** is no more than $1/10^{th}$ the impedance of the load **16**.

FIG. **7** is a schematic block diagram of another embodiment of the current threshold circuit **14**. In this embodiment, the current source **18** includes a plurality of output transistors T_1–T_n. The series impedance **30** includes a plurality of resistors R_1–R_n. The comparison module **32** includes a differential difference amplifier **46** and the reference voltage source **34** includes a band-gap reference **40**, a resistive divider **42** and a multiplexer **44**.

As shown, each of the output transistors of the current source **18** is coupled to a corresponding resistor of the series impedance **30**. The other node of each of the resistors in the series impedance **30** is coupled to the integrated circuit pin to drive the load **16**. In one embodiment, one of the resistors within the series impedance **30** may be sensed to provide the differential voltage **36**.

The voltage reference source **34** produces the reference voltage differential **38** by generating a reference voltage (Vref) via the band-gap reference **40**. The resistive divider **42** produces a plurality of reference voltages from the reference voltage. The multiplexer **44** is enabled to select two of the plurality of reference voltages, including the original reference voltage produced by the band-gap reference **40**, to produce the reference voltage differential **38**. Depending on the desired current limit threshold and the voltage drop across the sense resistor within the series impedance, the reference voltage differential **38** may be selected to have a relatively small differential value or a relatively large differential value. As an alternative configuration, the multiplexer **44** may only have one output to select a voltage for the negative leg of the reference voltage differential **38** and the band-gap reference **40** provides the positive leg of the reference voltage differential **38**.

The differential difference amplifier **46** amplifies the differential voltage **36** with respect to the reference voltage differential **38** to produce the excessive current indication **22**.

FIG. **8** illustrates the functionality of the comparison module **32**. In this embodiment the voltage across the load (V_{LOAD}) is represented over time and swings essentially from rail-to-rail (V_{SS} to V_{DD}). With reference to FIG. **7**, one node of the series impedance is coupled to the load and thus tracks the output voltage (V_{LOAD}). The other node of the series impedance **32**, with respect to the first node, provides the differential voltage **36**, which is based on the output current and the impedance of the series impedance. Thus, as the output current increases, the differential voltage **36** increases.

FIG. **8** further illustrates the reference voltage differential **38** as V**3** minus V**4**. V**3** may correspond to the bandgap reference voltage or the greater of the two voltages outputted by the multiplexer **44** and V**4** corresponds to the lesser of the two voltages outputted by the multiplexer **44** or the single output of the multiplexer **44**. The differential voltage **36** is illustrated as V**1** minus V**2**, where V**1** and V**2** correspond to the voltage drop across the series impedance **30**. In accordance with this embodiment, the amplifier output equals gain*[(V**1**−V**2**)−(V**3**−V**4**)]. If the difference between V**1** and V**2** ever exceeds the difference between V**3** and V**4**, then the excessive current indication is generated.

FIG. **9** is a schematic block diagram of another embodiment of a current sense threshold **14** operably coupled to an output transistor of current source **18**, which provides an output current to load **16** via an integrated circuit pin. In this embodiment, the current sense threshold circuit **14** includes a mirroring transistor (T_{mirror}), a cascode transistor (T_{cas}), a feedback module **50** and a sensing module **52**. In this embodiment, the mirroring transistor mirrors the current provided by the output transistor of current source **18**. The cascode transistor is gated via the feedback module, which keeps the drain voltage of the mirror transistor matching the drain voltage of the output transistor of current source **18** to insure accurate mirroring of the current produced by the output transistor as the output voltage swings from rail-to-rail.

The sensing module **52** is operably coupled to compare a representation of the current produced by the current mirroring transistor with a representation of a reference current (I_{ref}). The sensing module generates an excessive current indication **22** when the representation of the current produced by the current mirroring transistor compares unfavorably with the representation of the reference current level. Note that the representation of the currents produced by the mirroring transistor and the reference current may correspond to voltage signals, current signals and/or digital values produced via an analog-to-digital conversion.

FIG. **10** is a schematic block diagram of another embodiment of a current threshold circuit **14**. In this embodiment, the current threshold circuit **14** includes the feedback circuit **50**, the mirroring transistor, the cascode transistor and the current sense module **52** operably coupled to the output transistor of current source **18**. In this embodiment, the feedback module **50** includes an amplifier **60** and the current sense module **52** includes a sense resistor R and a comparator **62**.

In operation, the amplifier **60** provides a gate voltage to the cascode transistor that ensures that the drain voltage of the mirroring transistor matches or substantially matches the drain voltage of the output transistor T_{out} of current source **18**. By maintaining this drain voltage relationship, the mirroring transistor will accurately mirror the current of the output transistor even as the output voltage swings from rail-to-rail.

The sense resistor produces a voltage which represents the mirrored current. The voltage is compared with a reference voltage via comparator **62** to produce the excessive current indication **22** when the voltage imposed across the sense resistor R exceeds the reference voltage. Note that the sense resistor may be an on-chip resistor or an off-chip resistor. If an off-chip resistor is used, a more accurate representation of the mirror current may be produced since the tolerance of an off-chip resistor can be much greater than is obtainable via an on-chip resistor.

FIG. **11** is a schematic block diagram of another embodiment of a current threshold circuit **14**. In this embodiment, the current threshold circuit **14** includes the feedback circuit **50**, the mirroring transistor, the cascode transistor and the current sense module **52** operably coupled to the output transistor of current source **18**. In this embodiment, the feedback module **50** includes an amplifier **60** and the current sense module **52** includes a reference current source, a pair of transistors T**1**, T**2**, and a buffer (e.g., a pair of inverters).

In operation, the amplifier **60** provides a gate voltage to the cascode transistor that ensures that the drain voltage of the mirroring transistor matches or substantially matches the drain voltage of the output transistor T_{out} of current source **18**. By maintaining this drain voltage relationship, the mirroring transistor will accurately mirror the current of the output transistor even as the output voltage swings from rail-to-rail.

The sensing module **52** produces the excessive current indication **22** when the current through the mirroring transistor, and hence transistor T**1** of the sensing module **52**, produces a drain source voltage on transistor T**1** that exceeds a logic one input of the inverter. In this embodiment, the gate source voltage of T**1** is established by transistor T**2** and the reference current source. Based on the known voltage level for a logic one input of the inverter and the properties of transistors T**1** and T**2**, the reference current source can be set at a desired level to establish a desired gate source voltage, which in turn establishes the drain source voltage of T**1**.

As one of ordinary skill in the art will appreciate, the term "substantially" or "approximately", as may be used herein, provides an industry-accepted tolerance to its corresponding term and/or relativity between items. Such an industry-accepted tolerance ranges from less than one percent to twenty percent and corresponds to, but is not limited to, component values, integrated circuit process variations, temperature variations, rise and fall times, and/or thermal noise. Such relativity between items ranges from a difference of a few percent to magnitude differences. As one of ordinary skill in the art will further appreciate, the term "operably coupled", as may be used herein, includes direct coupling and indirect coupling via another component, element, circuit, or module where, for indirect coupling, the intervening component, element, circuit, or module does not modify the information of a signal but may adjust its current level, voltage level, and/or power level. As one of ordinary skill in the art will also appreciate, inferred coupling (i.e., where one element is coupled to another element by inference) includes direct and indirect coupling between two elements in the same manner as "operably coupled". As one of ordinary skill in the art will further appreciate, the term "compares favorably", as may be used herein, indicates that a comparison between two or more elements, items, signals, etc., provides a desired relationship. For example, when the desired relationship is that signal **1** has a greater magnitude than signal **2**, a favorable comparison may be achieved when the magnitude of signal **1** is greater than that of signal **2** or when the magnitude of signal **2** is less than that of signal **1**.

The preceding discussion has presented various embodiments of a current threshold circuit. Regardless of the embodiment, other circuits within an integrated circuit may use the excessive current indication to protect the output of the integrated circuit from damage due to short circuits and/or overload conditions. As one of average skill in the art will appreciate, other embodiments may be derived from the teaching of the present invention without deviating from the scope of the claims.

What is claimed is:

1. A current threshold circuit comprises:

a series impedance coupling an output of a current source to a load, wherein impedance of the series impedance is substantially less than impedance of the load;

a reference voltage source operably coupled to produce a reference voltage differential; and

a comparison module operably coupled to compare the reference voltage differential with a differential voltage of the series impedance, wherein the comparison module generates an excessive current indication when the differential voltage of the series impedance compares unfavorably to the reference voltage differential.

2. The current threshold circuit of claim **1**, wherein comparison module comprises:

a differential difference amplifier having a first set of inputs to receive the reference voltage differential and a second set of inputs to receive the differential voltage of the series impedance.

3. The current threshold circuit of claim **1**, wherein the reference voltage source comprises:

a band gap reference operably coupled to produce a reference voltage;

a resistive divider operably coupled to divide the reference voltage into a plurality of reference voltages; and a multiplexer operably coupled to select the reference voltage differential from two of the reference voltage and the plurality of reference voltages.

4. The current threshold circuit of claim 1 further comprises:

the output of the current source including a plurality of transistors; and

the series impedance including a plurality of resistors, wherein one node of each of the plurality of resistors is coupled to a corresponding one of the plurality of transistors and wherein the other node of each of the plurality of resistors are coupled together, wherein the differential voltage of the series impedance is provided by one of the plurality of transistors.

5. The current threshold circuit of claim 1, wherein the current source comprises at least one of:

an output of an amplifier; and

an output of a line driver.

6. A current threshold circuit comprises:

a current mirroring transistor operably coupled to a output transistor of a current source;

a cascode transistor operably coupled in series with the current mirroring transistor;

a feedback module operably coupled to generate a gate voltage for the cascode transistor such that a drain voltage of the current mirroring transistor substantially equals a drain voltage of the output transistor; and

a sensing module operably coupled to compare a representation of a current of the current mirroring transistor with a representation of a reference current level, wherein the sensing module generates an excessive current indication of the output transistor when the representation of the current of the current mirroring transistor compares unfavorably with the representation of the reference current level.

7. The current threshold circuit of claim 6, wherein the feedback module comprises:

an amplifier having a first input, a second input, and an output, wherein the first input is coupled to a drain of the output transistor, the second input is coupled to a drain of the cascode transistor, and the output is coupled to a gate of the cascode transistor.

8. The current threshold circuit of claim 6, wherein the sensing module comprises:

an off chip resistor coupled to a source of the cascode transistor to produce the representation of the current of the current mirroring transistor; and

a comparator operably coupled to compare a voltage imposed across the off chip resistor with a reference voltage that corresponds to the representation of the reference current level.

9. The current threshold circuit of claim 6, wherein the sensing module comprises:

an on chip resistor coupled to a source of the cascode transistor to produce the representation of the current of the current mirroring transistor; and

a comparator operably coupled to compare a voltage imposed across the on chip resistor with a reference voltage that corresponds to the representation of the reference current level.

10. The current threshold circuit of claim 6, wherein the representation of the current of the current mirroring transistor and the representation of a reference current level each comprise at least one of:

a voltage signal;

a current signal; and

a digital value produced by an analog to digital converter.

11. A high current output circuit of an integrated circuit (IC), wherein the high circuit output circuit comprises:

an amplifier circuit that includes an output current source; and

a current threshold circuit that includes:

a series impedance coupling an output of the output current source to a load, wherein impedance of the series impedance is substantially less than impedance of the load;

a reference voltage source operably coupled to produce a reference voltage differential; and

a comparison module operably coupled to compare the reference voltage differential with a differential voltage of the series impedance, wherein the comparison module generates an excessive current indication when the differential voltage of the series impedance compares unfavorably to the reference voltage differential.

12. The high current output circuit of claim 11, wherein comparison module comprises:

a differential difference amplifier having a first set of inputs to receive the reference voltage differential and a second set of inputs to receive the differential voltage of the series impedance.

13. The high current output circuit of claim 11, wherein the reference voltage source comprises:

a band gap reference operably coupled to produce a reference voltage;

a resistive divider operably coupled to divide the reference voltage into a plurality of reference voltages; and

a multiplexer operably coupled to select the reference voltage differential from two of the reference voltage and the plurality of reference voltages.

14. The high current output circuit of claim 11 further comprises:

the output of the current source including a plurality of transistors; and

the series impedance including a plurality of resistors, wherein one node of each of the plurality of resistors is coupled to a corresponding one of the plurality of transistors and wherein the other node of each of the plurality of resistors are coupled together, wherein the differential voltage of the series impedance is provided by one of the plurality of transistors.

15. A high current output circuit of an integrated circuit (IC), wherein the high circuit output circuit comprises:

an amplifier circuit that includes an output current source; and

a current threshold circuit that includes:

a current mirroring transistor operably coupled to a output transistor of the output current source;

a cascode transistor operably coupled in series with the current mirroring transistor;

a feedback module operably coupled to generate a gate voltage for the cascode transistor such that a drain voltage of the current mirroring transistor substantially equals a drain voltage of the output transistor; and

a sensing module operably coupled to compare a representation of a current of the current mirroring transistor with a representation of a reference current level, wherein the sensing module generates an excessive current indication of the output transistor when the representation of the current of the current mirroring transistor compares unfavorably with the representation of the reference current level.

16. The high current output circuit of claim **15**, wherein the feedback module comprises:

an amplifier having a first input, a second input, and an output, wherein the first input is coupled to a drain of the output transistor, the second input is coupled to a drain of the cascode transistor, and the output is coupled to a gate of the cascode transistor.

17. The high current output circuit of claim **15**, wherein the sensing module comprises:

an off chip resistor coupled to a source of the cascode transistor to produce the representation of the current of the current mirroring transistor; and

a comparator operably coupled to compare a voltage imposed across the off chip resistor with a reference voltage that corresponds to the representation of the reference current level.

18. The high current output circuit of claim **15**, wherein the sensing module comprises:

an on chip resistor coupled to a source of the cascode transistor to produce the representation of the current of the current mirroring transistor; and

a comparator operably coupled to compare a voltage imposed across the on chip resistor with a reference voltage that corresponds to the representation of the reference current level.

19. The high current output circuit of claim **15**, wherein the representation of the current of the current mirroring transistor and the representation of a reference current level each comprise at least one of:

a voltage signal;

a current signal; and

a digital value produced by an analog to digital converter.

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